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(71) Applicant(s) PSL Tools Limited (incorporated in the United Kingdom)  Badentoy Avenue, Portlethen, ABERDEEN, AB1 4YB, United Kingdom	(58) Field of Search UK CL (Edition P ) E1F FCJ FLA INT CL <sup>6</sup> E21B 7/28 10/32 29/00
(72) Inventor(s) Richard Alvin Armell Giancarlo Tomasso	
(74) Agent and/or Address for Service Murgitroyd & Company 373 Scotland Street, GLASGOW, G5 8QA, United Kingdom	

## (54) Underreamer with extendable cutting blades

(57) A downhole rotary cutting tool (10) comprises a tubular body (12) and a pair of pivotally mounted blades (14,15) movable between a retracted position as in figure 4 and an extended position as shown in figure 1. The upper cylindrical portion of the body (12) contains an annular blade actuating piston (16), normally biased in the blade retracted position by a spring (18). The piston (16) is movable in response to elevated fluid pressure within the body (12). The lower face of the piston (16) is attached to the upper ends of two dowels (20,21) which extend through the body (12) and contact a cam member (22) which is axially movable on a rectangular body portion (24) extending below the cylindrical portion (12). The cam (22) includes two axially extending fingers (26,27) for engaging cam surfaces of the respective blades (14,15). The blades (14,15) are biased in the retracted position by respective torsion springs (32) and can pivot around pin (28). Increased fluid pressure causes piston (16) to act against spring (18) which in turn causes the dowels (20,21) to move downwards and cam against the legs of the blades pushing the blades (14,15) into the extended position. The angular extension of the blades (14,15) can be controlled by the variation of the fluid pressure. Drilling fluid can be injected through ports above and below the blades serve to assist the cutting action and carry cuttings to the surface.

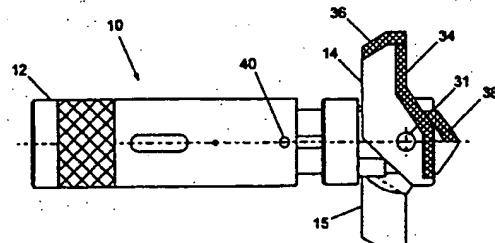


Fig. 1

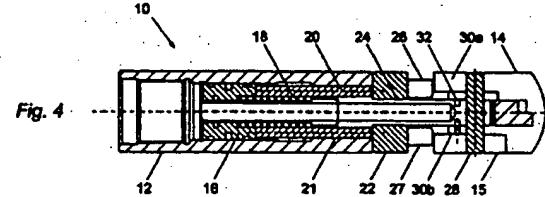


Fig. 4

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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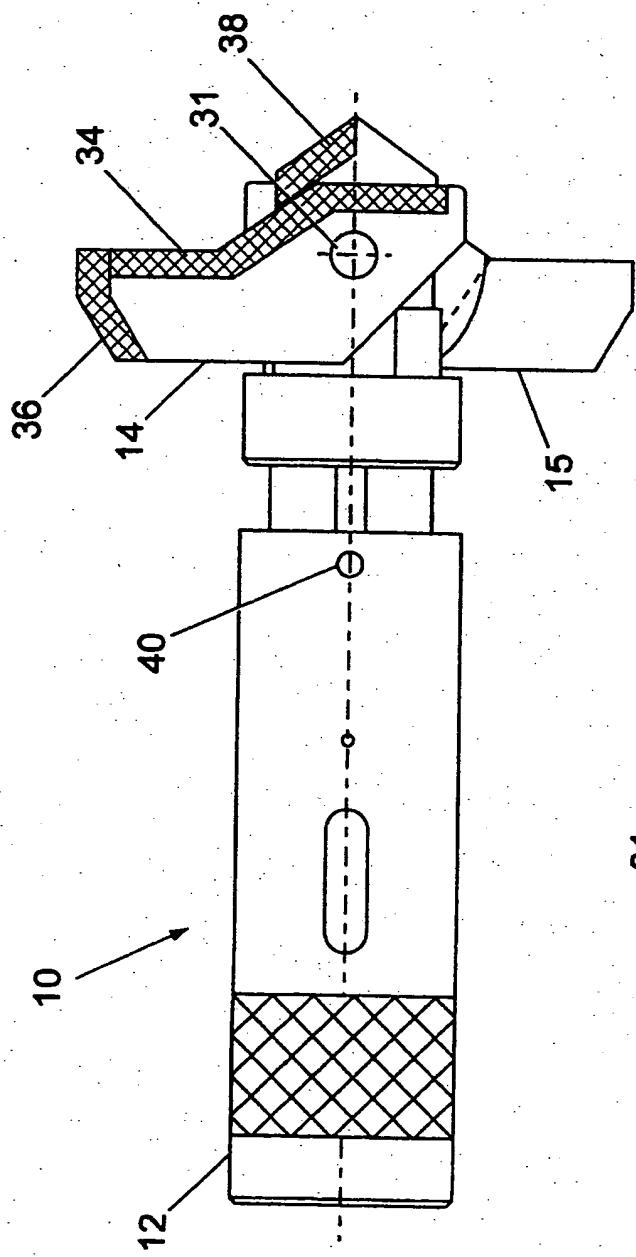


Fig. 1

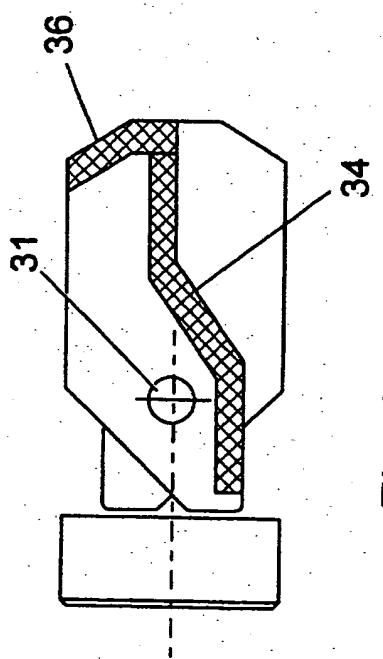


Fig. 2

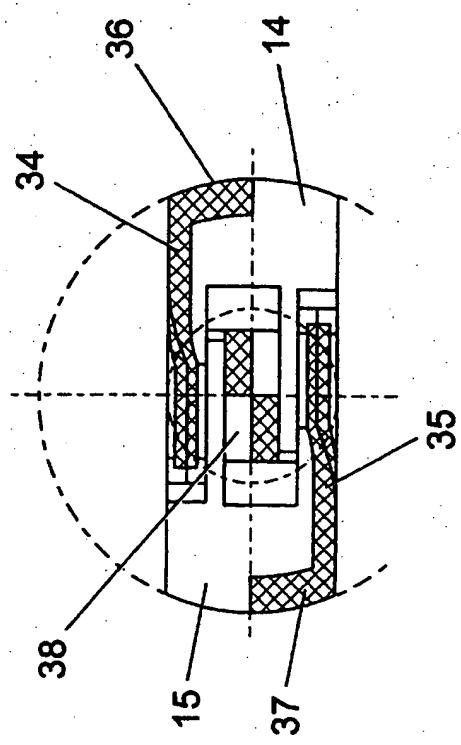


Fig. 3

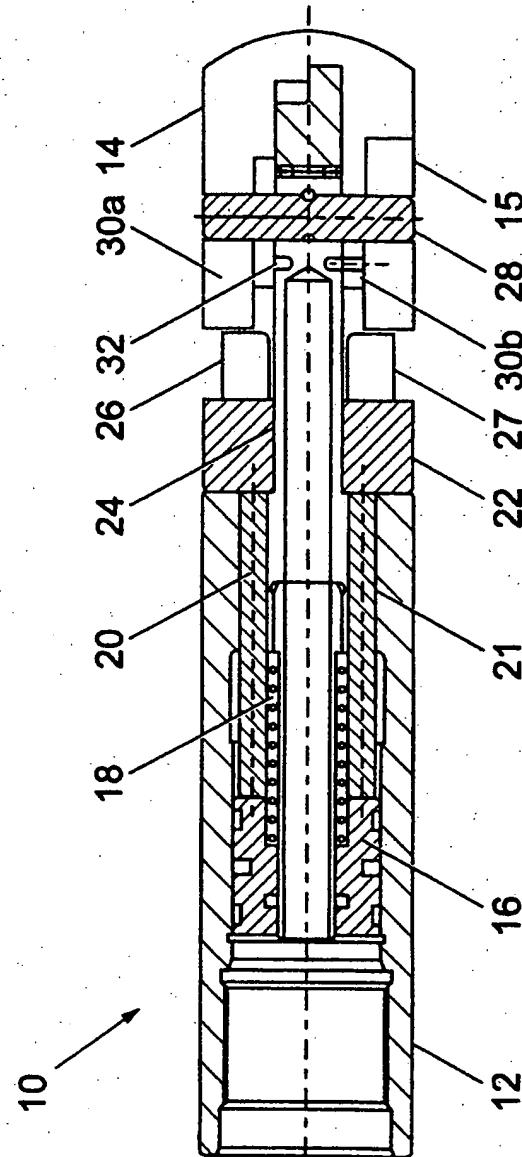


Fig. 4

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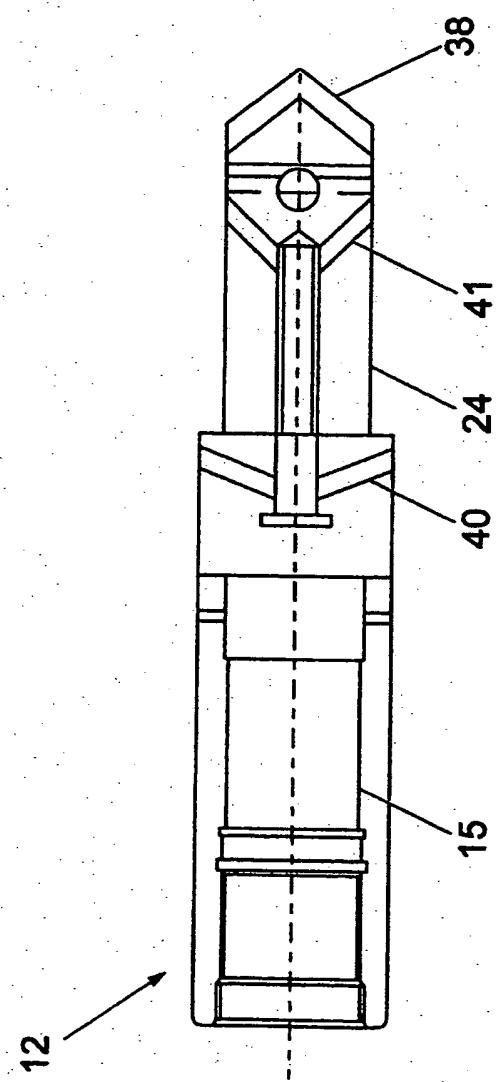


Fig. 5

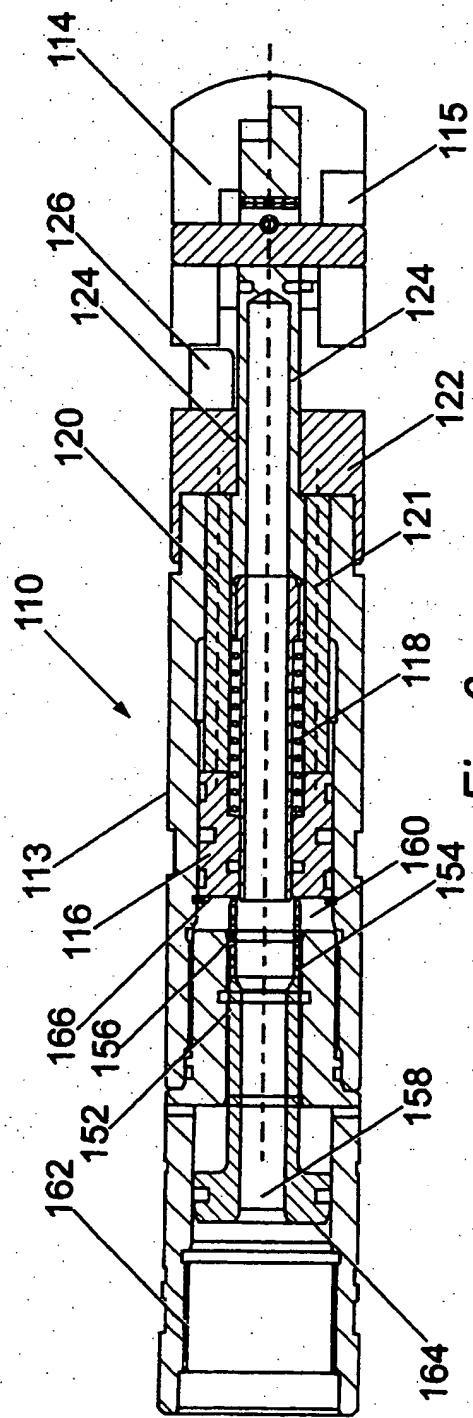


Fig. 6a

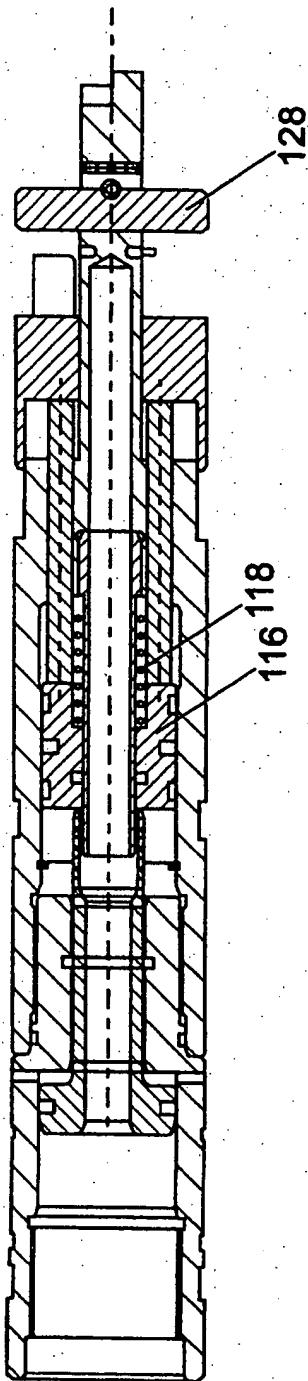


Fig. 6b

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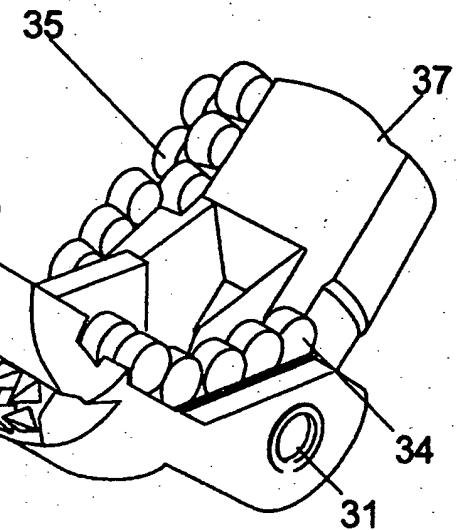


Fig. 7b

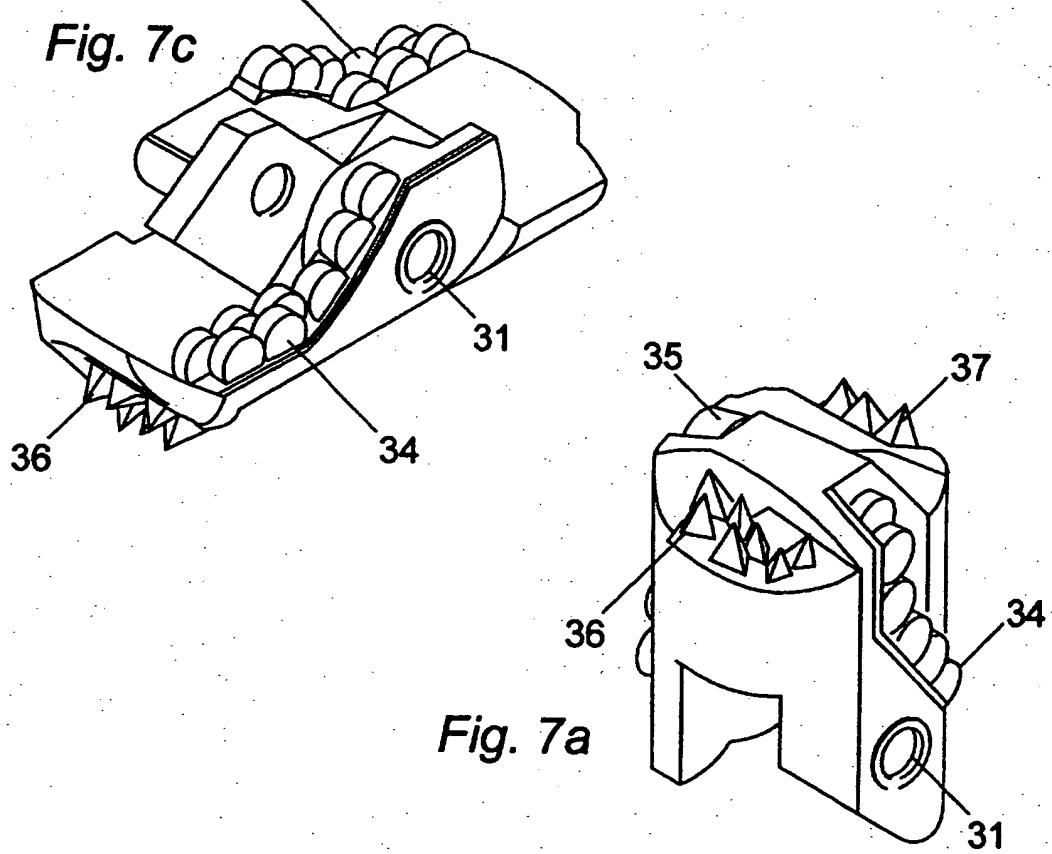


Fig. 7c

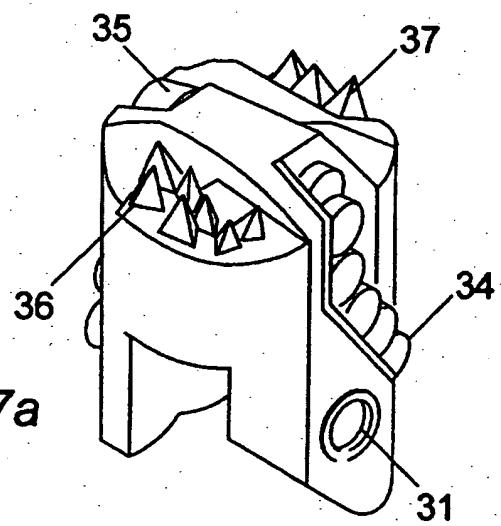


Fig. 7a

1     **"Downhole Tool"**

2

3     This invention relates to a downhole tool, and in  
4     particular to a downhole rotary cutting tool such as a  
5     section mill, underreamer or casing cutter.

6

7     When drilling or working on bores for use, for example,  
8     in oil or gas exploration or extraction, it is often  
9     desired to increase the diameter of a section of bore,  
10    which section of bore may be cased or uncased. This  
11    operation may be necessary to allow a larger diameter  
12    section of casing to be suspended below a section of  
13    smaller diameter casing or to cut casing to allow  
14    suspension of liner from the casing. The cutting  
15    operation may be carried out using a rotary cutting  
16    tool, which tools are known as, for example, section  
17    mills, underreamers or casing cutters. In the interest  
18    of brevity, the term "underreamer" will be used herein  
19    and is intended to encompass any rotary downhole  
20    cutting tool, including section mills and casing  
21    cutters, as the context permits.

22

23    Conventionally, underreamers comprise a slotted body  
24    for location in a drill string, the slots accommodating  
25    at least one pair of cutting blades mounted on a common

1 pivot pin. In the retracted position the blades lie  
2 within the body circumference. A piston within the  
3 body is movable in response to the internal fluid or  
4 mud pressure and acts on the blades to pivot the blades  
5 outwardly. In the retracted position the cutting face  
6 of each blade is directed downwardly, such that when  
7 the blades are extended the cutting faces extend  
8 downwardly and beyond the body diameter. Thus, the  
9 lateral extent or cutting diameter of the cutting faces  
10 is limited by the body diameter.

11

12 It is among the objectives of embodiments of the  
13 present invention to provide a rotary downhole cutting  
14 tool which may define a cutting diameter which is  
15 independent of the tool body diameter.

16

17 According to a first aspect of the present invention  
18 there is provided a downhole rotary cutting tool  
19 comprising a body and at least one blade pivotally  
20 mounted thereon and movable between a retracted  
21 position and an extended position, in the retracted  
22 position the blade lying substantially within the  
23 circumference defined by the body and a cutting face of  
24 the blade extending longitudinally of the body, and in  
25 the extended position the blade extending laterally of  
26 the body, and blade extending means for rotating the  
27 blade, preferably through an angle of greater than 45°,  
28 from the retracted position to the extended position.

29

30 The tool may be in the form of a section mill,  
31 underreamer or casing cutter.

32

33 The ability to rotate the blade through an angle of  
34 greater than 45° permits the tool to define a  
35 relatively large cutting area as, unlike conventional  
36 cutting tools, the extent of the cutting face of the

1. blade is not limited by the diameter of the cutter  
2. body. Preferably, the blade extending means rotates  
3. the blade through an angle of at least 60°, and more  
4. preferably an angle of at least 75°. In one preferred  
5. embodiment the blade extending means is capable of  
6. rotating the blade through approximately 90°, such that  
7. the blade extends substantially perpendicularly to the  
8. body axis. With this range of movement available the  
9. cutting width provided by the blade is substantially  
10. independent of the body diameter; in the retracted  
11. position the only limitation is the length of blade  
12. that may be accommodated. Further, in a preferred  
13. embodiment the degree of rotation of the blade is such  
14. that the downward forces experienced by the blade  
15. during a cutting operation, in response to weight  
16. applied to the tool from above, tend to maintain the  
17. blade in the extended configuration. This effect may  
18. be achieved by rotating the blade such that the  
19. resultant of the blade forces is directed outwardly of  
20. the blade pivot. With this arrangement, there is no  
21. requirement to continue to apply a blade extending  
22. force to the tool once the blade has been extended,  
23. other than the application of weight to the tool.  
24.  
25. Preferably also, the body defines a stop for supporting  
26. the extended blade. Typically, the stop will engage a  
27. rear or upper surface of the extended blade. The stop  
28. may bear a large proportion of the load applied to the  
29. blade and minimise the load that must be borne by the  
30. pivot. Most preferably, the stop and blade cooperate  
31. such that forces, including torsional forces, applied  
32. to the blade may be transferred directly to the body  
33. and are not all transferred to the body via the pivot.  
34. Preferably also, the blade is capable of cutting in  
35. positions between the retracted and fully extended  
36. positions; the tool may be located in a bore of a

1 diameter only slightly larger than the body and then  
2 rotated while the blade is extended such that the bore  
3 wall is cut to accommodate the extended blade which  
4 then defines a cutting face suitable for reaming and  
5 like operations.

6  
7 Preferably also, the tool is adapted to be located on  
8 the end of a string and the blade is located at the end  
9 of the tool, such that there are no limitations placed  
10 on the blade length.

11  
12 Preferably also, the end of the tool defines a drilling  
13 member, such as a spade point; this feature is useful  
14 for removing any blockages encountered in a bore during  
15 a milling or reaming operation. The drilling member  
16 may be exposed only once the blade has been extended.  
17 Alternatively, or in addition, in the extended position  
18 the blade defines a cutting face which extends across  
19 at least half of the diameter of the tool when the  
20 blade is extended.

21  
22 Preferably also, the blade is biased towards the  
23 retracted position.

24  
25 Preferably also, the tool includes at least two blades.  
26 Most preferably, the blades are mounted on a common  
27 pivot axis and in the extended positions extend from  
28 opposite sides of the body.

29  
30 Preferably also, in the extended position each blade  
31 end surface extends around at least a 30° segment of  
32 the circumference swept by the extended blades. Most  
33 preferably, each blade end extends around between 40°  
34 and 70° of the swept circumference, and in the  
35 preferred embodiments between 45° and 60°. Such areas  
36 are larger than those provided in conventional cutters

1 and serve to stabilise the tool in a bore more  
2 effectively.

3

4 Preferably also, the width of each blade corresponds to  
5 the body diameter. The blades are thus far more robust  
6 than conventional cutter blades which must be narrow  
7 enough to be accommodated in slots in the tool body  
8 when the blades are retracted.

9

10 Preferably also, each blade defines two transversely  
11 spaced bearing areas for engaging the pivot which  
12 locates the blades on the body. This arrangement  
13 reduces the stress and strain experienced by the pivot  
14 pin and the blade bearing areas.

15

16 The blade extending means may be fluid actuated,  
17 mechanically actuated, or actuated by a combination of  
18 fluid and mechanical forces. Most preferably, the  
19 blade extending means includes a piston movable in a  
20 cylinder defined by the body. The piston may be  
21 movable in response to pressure forces exerted by fluid  
22 pumped into the body from the surface. The piston and  
23 the cylinder may be annular, allowing provision of a  
24 central bore at least partially through the body, which  
25 bore may communicate with jets or nozzles for directing  
26 fluid towards the cutting face. The piston may be  
27 linked to a blade extending cam by longitudinally  
28 extending members. The blade extending means may  
29 include two or more pistons, to increase the level of  
30 actuating force available.

31

32 Preferably also, the body defines a fluid passage  
33 communicating with an outlet adjacent the blade, so  
34 that fluid may be passed through the body and exit the  
35 body as a jet to assist in the cutting operation.  
36 Outlets may be provided both above and below the

1       blades. In a preferred embodiment at least one fluid  
2       passage may be selectively closed or restricted by a  
3       member operatively associated with the blade extending  
4       means, which member opens the passage when the blade is  
5       moved to the extended position. The opening of the  
6       passage, and thus the positioning of the blade in the  
7       extended position, is detectable at the surface as a  
8       decrease in back pressure when pressurised fluid is  
9       applied to the tool through a supporting member, such  
10      as drill pipe or coil tubing.

11

12      Preferably also, the blade extending means is biassed  
13      towards the blade retracted position.

14

15      According to another aspect of the present invention  
16      there is provided a downhole rotary cutting tool  
17      comprising a body and at least one blade mounted  
18      thereon and movable between a retracted position and an  
19      extended position, the body defining a fluid passage  
20      communicating with an outlet adjacent the blade, so  
21      that fluid may be passed through the body and exit the  
22      body as a jet to assist in the cutting operation.

23

24      This aspect of the invention may be provided in  
25      combination with the first aspect of the invention as  
26      described above, and in combination with any of the  
27      preferred or alternative features of the first aspect  
28      as described above.

29

30      These and other aspects of the present invention will  
31      now be described, by way of example, with reference to  
32      the accompanying drawings, in which:

33

34      Figure 1 is a side view of an underreamer in  
35      accordance with a preferred embodiment of the present  
36      invention, showing the blades of the underreamer in the

1     extended position;

2         Figure 2 shows the blades of the underreamer of  
3         Figure 1 in the retracted position;

4         Figure 3 is an end elevation showing the blades of  
5         the underreamer of Figure 1 in the extended position;

6         Figure 4 is a sectional view of the underreamer of  
7         Figure 1;

8         Figure 5 is a sectional view of the body of the  
9         underreamer of Figure 1;

10         Figure 6a is a sectional view of a second  
11         embodiment of an underreamer according to the present  
12         invention;

13         Figure 6b is a sectional view of the underreamer  
14         of Figure 6a, with the blades of the underreamer  
15         removed; and

16         Figures 7a to c show the cutting blades for use  
17         with either embodiment of the underreamer in varying  
18         degrees of extension from the retracted position to the  
19         fully extended position.

20

21         The drawings illustrate a downhole rotary cutting tool  
22         in the form of an underreamer 10 for location on the  
23         lower end of a string of drill pipe (not shown); the  
24         tool may serve as a casing cutter, section mill or  
25         underreamer, but will be referred to herein as an  
26         underreamer. The underreamer comprises a tubular body  
27         12 carrying a pair of cutting blades 14, 15 on the  
28         lower end thereof. The blades 14, 15 are illustrated  
29         in the extended position in Figures 1 and 3, and in the  
30         retracted position in Figure 2.

31

32         An upper cylindrical portion of the body 12 contains an  
33         annular blade actuating piston 16 (Figure 4), normally  
34         biased to a blade retracted position by a spring 18.  
35         The piston 16 is movable in response to elevated fluid  
36         pressure within the body 12. The lower face of the

1 piston is attached to the upper ends of two dowels 20,  
2 which extend through the body 12 and contact a cam  
3 member 22 which is axially movable on a rectangular  
4 body portion 24 extending below the cylindrical portion  
5 12. The cam 22 includes two axially extending fingers  
6 26, 27 for engaging cam surfaces of the respective  
7 blades 14, 15.

8

9 The blades 14, 15 are held on the rectangular body  
10 portion by a common hinge pin 28. The blades 14, 15  
11 are U-shaped and each blade has two transversely spaced  
12 legs 30a and 30b on either side of the rectangular body  
13 portion 24. The pin 28 passes through apertures 31 in  
14 the legs 30a, 30b so that the blades 14, 15 may pivot  
15 about the pin 28. The blades 14, 15 are biased  
16 towards the retracted position by respective torsion  
17 springs 32.

18

19 As best seen in Figure 4, the width of each blade 14,  
20 15, at least at the blade end, corresponds to the body  
21 diameter, representing around 48° of the circumference  
22 swept by the extended blades.

23

24 Referring now to Figures 7a to 7c there is shown three-  
25 dimensional views of the blades 14, 15. Figures 7a  
26 shows the blades 14, 15 in the retracted position,  
27 whereas Figure 7c shows them fully extended. It will  
28 be appreciated that the blades 14, 15 may be used in an  
29 intermediate position, such as that shown in Figure 7b.

30

31 Each blade 14, 15 defines a primary cutting face 34, 35  
32 which extends laterally of the body when the blades 14,  
33 15 are in the extended position, as best shown in  
34 Figure 7c. The faces 34, 35 are provided with a  
35 hardened facing of, for example, tungsten carbide and  
36 it will be noted that each cutting face 34, 35 extends

1 over more than half of the diameter of the  
2 circumference swept by the extended blades. From  
3 Figure 2 of the drawings it will be noted that the  
4 faces 34, 35 lie longitudinally relative to the body 12  
5 when the blades are in the retracted position. Each  
6 blade also defines a cutting face 36, 37 on the blade  
7 end surface, which surfaces are provided with tungsten  
8 carbide facing.

9  
10 The cutting faces 36, 37 allow the underreamer to be  
11 operated without the blades fully extended. The  
12 projection of the faces 36, 37 allows the cutting faces  
13 to contact the inner bore and will abrade the surface  
14 of such as the drill string is rotated. Continued  
15 abrasion of the inner surface of the bore will allow  
16 the blades 14, 15 to reach their fully extended  
17 position.

18  
19 In addition to the cutting face as defined by the  
20 blades 14, 15, the end of the rectangular body portion  
21 24 also defines a spade point 38 provided with tungsten  
22 carbide facing.

23  
24 The cutting action of the various faces is assisted by  
25 the action of jets above and below the blades formed by  
26 fluid pumped from the surface through the body 12 and  
27 out of appropriate jetting ports 40, 41 (Figure 5) in  
28 the body 12, the fluid also serving to carry cuttings  
29 from the cutting face to the surface.

30  
31 In use, the underreamer 10 is mounted on the end of a  
32 length of drill pipe and run into a bore. At an  
33 appropriate depth, the drill string is rotated (in an  
34 anti-clockwise direction as viewed in Figure 3).  
35 Initially, the provision of the various springs 18, 32  
36 ensures that the blades 14, 15 remain in the retracted

1 position. However, even in this position, the cutting  
2 faces 36, 37 may be used for drilling a relatively  
3 small diameter circular area. Drilling fluid or "mud"  
4 is then pumped through the drill pipe from the surface,  
5 and the pressure differential between the interior of  
6 the body 12 and the bore annulus pushes the piston 16  
7 downwardly against the action of the spring 18. This  
8 movement pushes the dowels 20, 21 out of the  
9 cylindrical portion of the body and moves the cam  
10 member 22 into contact with the cam faces of the blades  
11 14, 15. The blades 14, 15 are thus pivoted outwardly,  
12 and if necessary the cutting faces 36, 37 are employed  
13 to cut the bore wall to allow the blades to move to  
14 their fully extended positions. The provision of the  
15 cam fingers 26, 27 extending beyond the body of the cam  
16 member 22 and engaging the blade cam surfaces permits  
17 the blades 14, 15 to be rotated through  $90^\circ$ , until they  
18 are substantially perpendicular to the body axis. On  
19 reaching the fully extended positions the head of each  
20 blade comes into contact with a side face of the  
21 rectangular body portion 24 and thus acts as a stop,  
22 and also reduces the cutting force load that must be  
23 borne by the hinge pin 28.

24

25 The illustrated blade configuration is primarily  
26 intended for reaming in a downward direction, though  
27 the provision of cutting faces 36, 37 which extend onto  
28 the upper surfaces of the extended blades allows the  
29 underreamer 10 to be used to cut in an upward direction  
30 if necessary.

31

32 It will be evident that the cutting faces 34, 35 define  
33 a relatively large area, thus increasing the cutting  
34 rate and decreasing blade wear. Also, the relatively  
35 wide blades 14, 15 serve to stabilise the underreamer  
36 10 in the bore, and of course provide blades which are

1 relatively robust and less likely to be damaged during  
2 reaming by normal drilling operations.

3  
4 It will also be apparent that the extended blade  
5 configuration, that is the extended blades being over  
6 centre, leads to the forces experienced by the blades  
7 tending to maintain the blades in the extended  
8 position, unlike conventional pivoting blade cutters in  
9 which the forces experienced by the blades tend to  
10 force the blades towards the retracted position.

11 Further, as the forces experienced by the blades 14, 15  
12 are transferred to the body 12 via the upper or rear  
13 surfaces of the blades, the arms of the U-shape and the  
14 hinge pin 28, and there are no significant forces  
15 required between the cam fingers 26, 27 and the blade  
16 surfaces to maintain the blades extended, key seating  
17 of the blade cam surfaces and the cam fingers 26, 27 is  
18 most unlikely.

19  
20 The term "key seating" refers to the groove which may  
21 be formed by continued application of the cam surfaces  
22 to the cam fingers 26, 27. In conventional tools, in  
23 order to keep the blades of the tool extended whilst  
24 reaming, the cam fingers must abut against the blades  
25 at all times. As the pressure required to keep the  
26 blades extended can be fairly substantial during  
27 reaming operations, a key or groove is often formed in  
28 the blade surface due to the relative movement of the  
29 blade during such operations. This groove can prevent  
30 the blades extending, or retracting, as the cam fingers  
31 may become stuck in the groove.

32  
33 However, in the present invention, once the cam fingers  
34 26, 27 have extended the blades 14, 15, the force  
35 required to extend the blades can be removed. This is  
36 because the weight of the drillstring above the tool

1 10, 110, will keep the blades extended without any  
2 additional force due to the inherent design of the tool  
3 10, 110. In this way, the possibility of creating such  
4 a groove is substantially reduced.

5

6 It will be evident to those of skill in the art that  
7 the above-described embodiments offer numerous  
8 advantages over conventional cutting tools. It will  
9 further be evident to those of skill in art that the  
10 above-described embodiments are merely exemplary of the  
11 present invention, and that various modifications and  
12 improvements may be made thereto without departing from  
13 the scope of the present invention. In a further  
14 embodiment of the invention a skirt may be provided on  
15 the cam member 22 to cover the gap that is otherwise  
16 formed between the lower end of the cylindrical body  
17 portion 15 and the upper end of the cam member 22 as  
18 the blades are extended. The skirt prevents debris  
19 filling the gap which might prevent retraction of the  
20 cam member 22 and thus retraction of the blades. In  
21 the blade retraction position the skirt may cover the  
22 jetting points 40, these being exposed only when the  
23 blades are fully extended. The exposure of the ports  
24 40, indicating that the blades are fully extended, will  
25 be detectable at the surface as a drop in fluid back  
26 pressure.

27

28 Referring now to Figs 6a and 6b, there is shown a  
29 second embodiment of underreamer, generally designated  
30 110, according to the present invention. The  
31 underreamer 110 is substantially the same as the  
32 previous tool 10, except for the inclusion of an  
33 intensifier piston 152. Note that similar parts have  
34 been designated with the same reference numeral,  
35 prefixed by 1.

36

1 The purpose of the intensifier piston 152 is to  
2 increase the force applied to the piston  
3 116. The intensifier piston 152 is positioned behind  
4 the piston 116, as shown in Fig 6a. Although only one  
5 such intensifier piston 152 is shown, it will be  
6 generally appreciated that any number of such pistons  
7 152 may be cascaded in series to further increase the  
8 force applied to the piston 116.

9

10 Intensifier piston 152 has a plurality of apertures 154  
11 therein at a front portion 156. The apertures 154 in  
12 the front portion 156 provide a fluid communication  
13 between the interior 158 of the secondary piston 152  
14 and thus the bore of the tubing behind the tool 110,  
15 and an annular chamber 160 which is behind the piston  
16 116.

17

18 In use, drilling fluid or mud is pumped down the  
19 central bore 162 of the tool 110 and the interior 158  
20 of the secondary piston 152. The fluid pressure at the  
21 rear face of the intensifier piston 152 forces it  
22 downwards from the position shown in Fig. 6a against  
23 the piston 116 with which it engages. The downward  
24 movement of the piston 116 pushes down the dowels 120,  
25 121 which forces the skirt 122 downwards against the  
26 blades 114, 115 as shown in Fig. 6b and forces them  
27 outwards, as in the previous embodiment.

28

29 In addition to providing the movement of the  
30 intensifier piston 152 acting directly against the  
31 piston 116, the drilling fluid pumped down the central  
32 bore 162 and though the interior 158 of the intensifier  
33 piston 152 passes both to the end of the tool and  
34 through apertures 154 into the annular chamber 160.  
35 The force of the fluid in the chamber 160 acts against  
36 the rear face 166 of the piston 116 and thus increases

1 the downward force on the piston 116. Hence, the  
2 intensifier piston 152 increases the surface area  
3 against which the force of the drilling fluid can act.

4  
5 It will be appreciated that a number of such  
6 intensifier pistons 152 may be used in series, thereby  
7 increasing the surface area which is available  
8 proportionally and thus the force exerted on the piston  
9 116 to extend the blades 114, 115.

10  
11 This increase in force applied to the piston 116  
12 results in an increase in the force, for the same  
13 pumping pressure, which is applied to the blades 114,  
14 115 to keep them extended. This allows the tool 110 to  
15 back ream i.e. to cut while being retracted from a  
16 borehole. The increase in force applied to the blades  
17 114, 115 keeps them extended even when a retracting  
18 force, such as that applied by the retraction of the  
19 tool 110, is applied to them.

20  
21 The movement of the skirt 122 provides a means for  
22 reducing the back pressure in the system when the  
23 blades are fully extended. In Fig 6a, the skirt 122 is  
24 shown in the retracted position. However, in Fig. 6b  
25 the pressure applied by the drilling fluid has extended  
26 the dowels 120, 121 as previously described, which act  
27 against the skirt 122 forcing it downwards into the  
28 position as shown in Fig. 6b.

29  
30 When the pressure of the fluid has fully extended the  
31 blades 114, 115, they tend to remain extended due to  
32 the downward force provided by the weight of the drill  
33 string above it. In this extended position, the skirt  
34 122 uncovers a plurality of apertures (not shown) which  
35 extend through the rectangular body portion 124, to  
36 allow passage of the drilling fluid from the central

1 bore of the tool 110. Thus, the fluid pressure which  
2 was required to extend the blades 114, 115 is reduced  
3 upon movement of the skirt 122 to expose the apertures,  
4 thereby allowing the drilling fluid to escape into the  
5 borehole.

6

7 The venting of drilling fluid through the apertures  
8 reduces the back pressure in the system which is a  
9 substantial advantage of the present invention. When  
10 the tool 110 is driven by a hydraulic motor located  
11 further up the drill string, for example, any reduction  
12 in the back pressure at the motor allows it to operate  
13 more efficiently. In addition, the circulation of the  
14 drilling fluid out of the apertures helps to remove  
15 debris which collects in the borehole.

16

17 The inclusion of one or more intensifier pistons, as in  
18 the above described embodiment, offers a substantial  
19 advantage over conventional cutting tools. The  
20 intensifier piston increases the downward force applied  
21 to the blades by increasing the surface area against  
22 which the drilling fluid may act.

23

24 Furthermore, the provision of the skirt and apertures  
25 in the rectangular body allows the back pressure in the  
26 system to be substantially reduced when the blades are  
27 fully extended.

28

29 Modifications and improvements may be made to the  
30 foregoing without departing from the scope of the  
31 present invention.

32

1   **CLAIMS:**

2

3   1. A downhole tool comprising a body and at least one  
4   blade pivotally mounted thereon and movable between a  
5   retracted position and an extended position, in the  
6   retracted position the blade lying substantially within  
7   the circumference defined by the body and a cutting  
8   face of the blade extending longitudinally of the body,  
9   and in the extended position the blade extending  
10   laterally of the body, and blade extending means for  
11   rotating the blade from the retracted position to the  
12   extended position.

13

14   2. A downhole tool as claimed in claim 1, wherein the  
15   blade can be extended through an angle of 45° or  
16   greater.

17

18   3. A downhole tool as claimed in claim 1 or claim 2,  
19   wherein the blade is orientated downwards in use.

20

21   4. A downhole tool as claimed in any preceding claim,  
22   wherein the degree of rotation of the blade is such  
23   that the downward forces acting on the blade during a  
24   cutting operation tend to maintain the blade in the  
25   extended configuration.

26

27   5. A downhole tool as claimed in any preceding claim,  
28   wherein the blade extending means can rotate the blade  
29   through an angle of at least 60°.

30

31   6. A downhole tool as claimed in either preceding  
32   claim, wherein the blade extending means can rotate the  
33   blade through an angle of at least 75°.

34

35   7. A downhole tool as claimed in any preceding claim  
36   wherein the blade extending means is capable of

1. rotating the blade through approximately 90°.

2.

3. 8. A downhole tool as claimed in any preceding claim,  
4. wherein, the body has a stop for supporting the  
5. extended blade.

6.

7. 9. A downhole tool as claimed in claim 8, wherein the  
8. stop and blade cooperate such that forces applied to  
9. the blade are transferred to the body through the stop.

10.

11.

12. 10. A downhole tool as claimed in any preceding claim,  
13. wherein the blade is capable of cutting in positions  
14. between the retracted and fully extended positions.

15.

16. 11. A downhole tool as claimed in any preceding claim,  
17. wherein the tool is adapted to be located on the end of  
18. a string.

19.

20. 12. A downhole tool as claimed in any preceding claim,  
21. wherein the blade is located at the end of the tool,  
22. such that there are no limitations placed on the blade  
23. length.

24.

25. 13. A downhole tool as claimed in any preceding claim,  
26. wherein the end of the tool has a drilling or cutting  
27. member.

28.

29. 14. A downhole tool as claimed in claim 13, wherein  
30. the drilling or cutting member is a spade point.

31.

32. 15. A downhole tool as claimed in either one of claims  
33. 13 or 14, wherein the drilling or cutting member is  
34. exposed only once the blade has been extended.

35.

36. 16. A downhole tool as claimed in any preceding claim,

1       wherein in the extended position the blade has a  
2       cutting face which extends across at least half of the  
3       diameter of the tool when the blade is extended.

4

5       17. A downhole tool as claimed in any preceding claim,  
6       wherein the blade is biassed towards the retracted  
7       position.

8

9       18. A downhole tool as claimed in any preceding claim  
10      wherein the tool includes at least two blades.

11

12      19. A downhole tool as claimed in claim 18, wherein  
13      the blades are mounted on a common pivot axis and in  
14      the extended positions extend from opposite sides of  
15      the body.

16

17      20. A downhole tool as claimed in either of claims 18  
18      or 19, wherein in the extended position each blade end  
19      surface extends around at least a 30° segment of the  
20      circumference swept by the extended blades.

21

22      21. A downhole tool as claimed in any one of claims 18  
23      to 20, wherein each blade end extends around between  
24      40° and 70° of the swept circumference.

25

26      22. A downhole tool as claimed in any one of claims 18  
27      to 21 wherein each blade end extends around between 45°  
28      and 60°.

29

30      23. A downhole tool as claimed in any preceding claim  
31      wherein the width of the or each blade corresponds to  
32      the body diameter.

33

34      24. A downhole tool as claimed in any one of claims 15  
35      to 23, wherein each blade has two transversely spaced  
36      bearing areas for engaging the pivot which locates the

1       blades on the body.

2

3       25. A downhole tool as claimed in any preceding claim,  
4       wherein the blade extending means is fluid-actuated.

5

6       26. A downhole tool as claimed in any one of claims 1  
7       to 24, wherein the blade extending means is  
8       mechanically-actuated.

9

10      27. A downhole tool as claimed in any one of claims 1  
11      to 24, wherein the blade extending means is actuated by  
12      a combination of fluid and mechanical forces.

13

14      28. A downhole tool as claimed in any preceding claim,  
15      wherein the blade extending means includes a piston  
16      movable in a cylinder defined by the body.

17

18      29. A downhole tool as claimed in claim 28, wherein  
19      the piston is movable in response to forces exerted by  
20      fluid pumped into the body from the surface.

21

22      30. A downhole tool as claimed in claim 28 or claim  
23      29, wherein the piston and the cylinder are annular,  
24      allowing provision of a central bore at least partially  
25      through the body, which bore may communicate with jets  
26      or nozzles for directing fluid towards the cutting  
27      face.

28

29      31. A downhole tool as claimed in any preceding claim,  
30      wherein the blade has a blade extending cam on which  
31      the blade extending means acts.

32

33      32. A downhole cutting tool as claimed in claim 31,  
34      wherein the piston is linked to the blade extending cam  
35      by longitudinally extending members.

36

1       33. A downhole tool as claimed in any preceding claim  
2       wherein the blade extending means includes two or more  
3       pistons, to increase the level of actuating force  
4       available.

5

6       34. A downhole tool as claimed in any preceding claim,  
7       wherein the body defines a fluid passage communicating  
8       with an outlet adjacent the blade, so that fluid may be  
9       passed through the body and exit the body as a jet to  
10      assist in the cutting operation.

11

12      35. A downhole tool as claimed in claim 30 or 34,  
13      wherein the outlets are provided both above and below  
14      the blades.

15

16      36. A downhole tool as claimed in claim 34 or 35,  
17      wherein at least one fluid passage is opened, closed or  
18      restricted when the blade is moved to the extended  
19      position.

20

21      37. A downhole tool as claimed in claim 36, wherein  
22      the opening of the passage, and thus the positioning of  
23      the blade in the extended position, is detectable at  
24      the surface as a decrease in back pressure when  
25      pressurised fluid is applied to the tool.

26

27      38. A downhole tool as claimed in any preceding claim  
28      wherein the tool is an underreamer.

29

30      39. A downhole tool comprising a body and at least one  
31      blade mounted thereon and movable between a retracted  
32      position and an extended position, the body defining a  
33      fluid passage communicating with an outlet adjacent the  
34      blade, so that fluid may be passed through the body and  
35      exit the body as a jet to assist in the cutting  
36      operation.



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Application No: GB 9725821.4  
Claims searched: 1-38

Examiner: Robert Fender  
Date of search: 8 April 1998

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.P): E1F: FCJ, FLA

Int CI (Ed.6): E21B 7/28, 29/00

Other:

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2262758 A (HAILEY) in particular figures 2 & 3 and page 5 lines 28-37	1-11, 13, 15, 17-23, 25-31, 33, 34, 38
X	GB 2245626 A (HAILEY) in particular figures 2 & 3 and page 5 lines 28-37	1-11, 13, 15, 17-23, 25-31, 33, 34, 38
X	GB2211221 A (HAILEY) in particular figures 4 & 5	1-11, 13, 15, 17-23, 25-31, 33, 34, 38
X	GB 2172315 A (LUEN) in particular figure 1	1, 2, 4-7, 10, 11, 15, 17-19, 26, 38
X	GB 1596308 (WEAVER AND HURT LIMITED) in particular figures 1-3	1, 2, 4, 10, 11, 13, 15-19, 38
X	US 4938291 (LYNDE AND PRICE) in particular figures 1 & 2	1, 2, 4, 10, 11, 17-19, 38

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